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Research paper

Multi-actor Horizon 2020 projects in agriculture, forestry and related sectors: A Multi-level Innovation System framework (MINOS) for identifying multi-level system failures

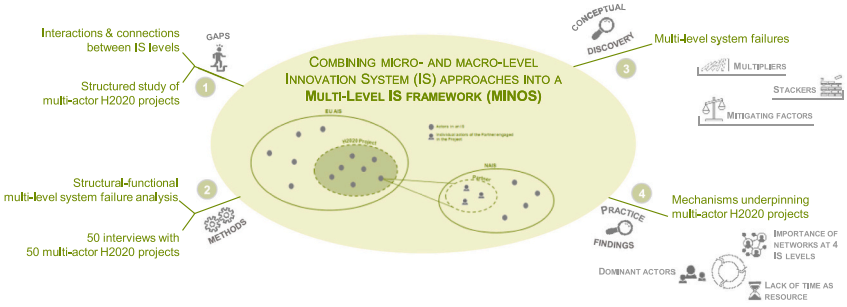
Evelien Cronin [a,*], Andrew Fieldsend [b], Elke Rogge [a], Thomas Block [c]

[a] Flanders Research Institute for Agriculture, Fisheries and Food, Burg. van Gansberghelaan, 92,9820 Merelbeke, Belgium
[b] Agrárközgazdasági Intézet Nonprofit Kft, Zsil utca 3-5, 1093 Budapest, Hungary
[c] Ghent University, Department of Political Sciences, Centre for Sustainable Development, Poel, 16, 9000 Ghent, Belgium

HIGHLIGHTS

- Systematic research on multi-actor H2020 projects for research and innovation in agriculture and related sectors is scarce.
- A Multi-level Innovation System framework is developed to enhance understanding of multi-actor H2020 project functioning.
- A systematic and comparative analysis of 50 multi-actor H2020 projects based on semi-structured key informant interviews.
- Identification and definition of multi-level system failures; multipliers, stackers and the presence of mitigating factors.
- The MINOS framework contributes to the conceptual discussion on the study of interdependencies between different IS levels.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: The key European Union (EU) policy instrument in support of innovation in agriculture, forestry and related sectors is the European Innovation Partnership for Agricultural Productivity and Sustainability. It applies the 'interactive innovation model' which brings together actors with complementary types of knowledge. This policy instrument is implemented inter alia through multi-actor projects funded via the Horizon 2020 (H2020) Research and Innovation (R&I) programme.

OBJECTIVE: Although the multi-actor H2020 projects account for a substantial part of EU project funding for agriculture, forestry and related sector R&I, systematic and comparative research on the multi-actor H2020 projects is scarce. This is partly due to a lack of a structured analytical approach to accommodate the differences in institutional, cultural and social contexts which influence the co-innovation and social learning processes in these multinational, multi-actor partnerships. To this end, we argue that the analytical integration of the micro-

* Corresponding author.
E-mail address: evelien.cronin@ilvo.vlaanderen.be (E. Cronin).

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and macro-level innovation system (IS) perspectives is necessary to understand fully the mechanisms underlying the functioning of, and the co-innovation process within, multi-actor H2020 projects.
METHODS: This analytical gap is addressed with the development of an integrated, Multi-level Innovation System framework (MINOS) and its application to 50 multi-actor H2020 projects. MINOS recognises the presence, influence of and interaction between multiple levels of IS in such projects.
RESULTS AND CONCLUSIONS: We distinguish four levels of IS: the European Agricultural Innovation System (EU AIS), the National Agricultural Innovation System (NAIS), the H2020 project and the partner organisations involved in the project (Partner). Our analysis of the system failures that occurred across most of the 50 cases allowed us to identify and conceptualise two categories of 'multi-level system failures', namely multipliers and stackers, and the presence of mitigating factors.
SIGNIFICANCE: The MINOS analytical framework enabled a) a better understanding of the underlying mechanisms of co-innovation in multi-actor H2020 projects and b) contributed to addressing the theoretical and conceptual gaps in terms of studying the interconnection and interdependence of different IS levels.

1. Introduction

European Union (EU) policy defines innovation as the outcome of an interactive and co-evolutionary process engaging multiple types of actors (EIP-AGRI Service Point, 2017). An example of such an EU policy instrument is the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI). This was set up by the EU as an instrument to 'speed up' innovation in agriculture, forestry and related sectors by creating synergies between different policy programmes both at the EU and Member State levels and to build bridges between research and practice (DG AGRI, 2018). Central to the EIP-AGRI is the application of the 'interactive innovation model', which is defined as: "*the collaboration between various actors to make best use of complementary types of knowledge (scientific, practical, organisational etc.) in view of co-creation and diffusion of solutions/opportunities ready to implement in practice.*" (EIP-AGRI Service Point, 2017, p. 3).

The 'interactive innovation model' is applied via a classical tool of EU policy implementation: project funding (Büttner and Leopold, 2016). Projects funded in the frame of the EIP-AGRI are required to apply the 'multi-actor approach' (MAA) and focus on real problems that farmers, foresters or other 'users' are facing. The funding is provided via two distinct mechanisms: a) the national Rural Development Programmes under the Common Agricultural Policy in the form of Operational Groups (OGs) and b) the Horizon 2020 (H2020) Research and Innovation (R&I) programme in the form of multi-actor projects. The latter may (or may not) be 'research' projects[1], and their activities are expected to be based on 'co-innovation' between actors with complementary knowledge (and other resources) 'all along the project', i.e., from defining the problem to implementing the solution.

Although the EIP-AGRI approach is relatively new, having been implemented from 2013 onwards, OGs have already been widely studied (e.g. Coffey International, 2016; Cristiano and Proietti, 2018; Molina et al., 2021). By contrast, systematic and comparative research on the multi-actor H2020 projects is scarce. This is despite the fact that, to date, 180 projects have been allocated around EUR 1 billion of funding representing 27% of all H2020 funding foreseen under the heading of bioeconomy and agriculture, forestry and rural development (EIP-AGRI Service Point, 2019). Since funding for MAA projects will be increased under the 2021–2027 Horizon Europe programme (European Parliament Research Service, 2019), the successor to H2020, it has become even more pertinent to study the underlying mechanisms of the functioning of multi-actor H2020 projects. Insights into how H2020 projects are set up or how they integrate various types of knowledge and negotiate decisions are currently lacking although their potential contribution to a more sustainable agrifood system can be significant.

Studies on multinational R&I projects by Klerkx et al. (2017) and Ingram et al. (2020) indicated the lack of a structured approach to accommodate differences in institutional, cultural and social contexts which influence co-innovation and social learning processes, while Kernecker et al. (2021) were confronted with difficulties in studying the networks of actors involved in an innovation process related to the development of Smart Farming technologies in different countries as part of a H2020 project. Klerkx et al. (2017) illustrated a possible approach for analysing the impacts different dimensions of institutions can have on the functioning of a multinational project. As H2020 projects must cover at least three EU Member States and consortia should include several types of partner organisations, they are subject to the specific institutional conditions and actor constellations related to each of these contexts located at different levels (i.e., project, technology, country and partner organisation).

This recognition of the existence of different levels of context is the subject of ongoing debates in the application of Innovation System (IS) frameworks, as these findings support the argument that an IS can entail different IS levels that are interlinked and interconnected, while mechanisms between them can influence each other's functioning (Van Lancker et al., 2016; Kieft et al., 2017; Klerkx et al., 2017). It indicates the need to further explore how to reconcile and accommodate the study of co-innovation processes that cross different scalar (micro- or macro-level), geographical (national, regional), paradigmatic (technological, disciplinary, mission-oriented) and sector IS boundaries (Berthet et al., 2018; de Boon et al., 2021; Kernecker et al., 2021; Klerkx et al., 2012; Klerkx and Begemann, 2020; Pigford et al., 2018). Yet, research to date often focusses on one IS level only.

For many researchers in agriculture, forestry and related sectors, the preferred tool for studying the macro-level is the Agricultural Innovation System (AIS). For example, Lamprinopoulou et al. (2014), Kebebe et al. (2015) and Turner et al. (2016) applied a systemic AIS framework integrating the different streams of analyses building on their combined strengths. This framework allows for an in-depth screening of patterns underlying issues influencing the performance of macro-level IS. The boundaries of AIS analyses are often set at the national level and sometimes further specified to a specific sector (e.g. dairy in the case of Kebebe et al., 2015).

On the other hand, the micro-level IS, or the innovating entity (such as multi-actor H2020 projects), has received far less attention. As a response, Van Lancker et al. (2016) developed the Organisational Innovation System (OIS) approach which focusses explicitly on this micro-level. Projects can be conceptualised as temporary organisations (Sydow and Braun, 2018) and Fieldsend et al. (2020) applied the OIS concept to multi-actor co-innovation partnerships in agriculture and forestry. The OIS approach of Van Lancker et al. (2016) emphasises the connections to higher level IS, but does not systematically link them.

While both these IS frameworks offer an approach to identify the underlying mechanisms of the innovation process at different IS levels and conceptualise that the characteristics of an IS depend to some extent on the contexts in which they are embedded, there are few approaches to empirically test this idea (Bergek et al., 2015; de Boon et al., 2021;

[1] These project can undertake three 'types of action'; i.e., 'Research and Innovation Actions' (RIA), 'Innovation Actions' (IA) and 'Thematic Networks' (TN).

Kernecker et al., 2021; Walshok et al., 2014). Hence, there is a lack of a structured framework or approach to accommodate the study of the interdependence between different IS levels.

Both the AIS and the OIS frameworks focus on identifying systemic problems, called 'system failures', which pose barriers to the functioning of an IS (Kieft et al., 2017). Additionally, not only the separate instances of system failures are of relevance, but also the existence of blocking mechanisms in IS created by clusters of system failures (Turner et al., 2016; Kieft et al., 2017). Literature further suggests that not only the combination of system failures in one IS level, but also the interconnection and interdependence between failures at different levels, influences IS performance and functioning (Eastwood et al., 2017; Kernecker et al., 2021; Vermunt et al., 2022).

In this paper, we therefore argue that the analytical integration of the micro- (OIS) and macro- (AIS) level IS perspectives is necessary to understand fully the mechanisms underlying the functioning of, and the co-innovation process within, multinational, multi-actor co-innovation partnerships in the form of multi-actor H2020 projects. We address this analytical gap by developing and applying an integrated, Multi-level Innovation System framework (MINOS) which recognises the presence, influence and interdependence in such projects of multiple IS levels. This framework spans four IS levels; the European Agricultural Innovation System (EU AIS), the National Agricultural Innovation System (NAIS), the H2020 project and the partner organisations involved in the project (Partner). MINOS enables us to study the linkages and interactions between the four IS levels and to identify and categorise system failures, lock-ins, blocking mechanisms or success factors at the different levels and their intersections. The AIS and OIS frameworks are compatible and complementary because they apply a similar conceptualisation referring to a similar body of knowledge (e.g., Bergek et al., 2008; Hekkert et al., 2007; Klein Woolthuis et al., 2005), apply the same analytical approach while focussing on different yet interconnected IS levels. The integration of these two frameworks is explained in detail in section 2.

Our IS analysis is based on a dataset of 50 multi-actor H2020 projects, each crossing multiple organisational and national boundaries. The case-by-case semi-structured interviews allowed us to identify key emerging patterns in the different IS levels and to test the applicability of the MINOS framework. This broad and exploratory analysis is the first step towards more in-depth case studies of multinational, multi-actor co-innovation partnerships and is a way to test and confirm the applicability of the analytical framework for this future work. Through the application of the MINOS lens to 50 multi-actor H2020 projects, we were able to classify and define a new set of 'multi-level' system failures which stem from the interlinkages and connections between the four IS levels described above. In this way, we build an improved understanding of how these levels and related system failures are interconnected and interdependent which enables improved targeting of different types of interventions.

In the following sections of this paper, we firstly present the conceptual and analytical building blocks for the MINOS framework. We then test and apply the MINOS framework to 50 multi-actor H2020 projects, identifying barriers, drivers and system failures which span multiple levels and which influence the mechanisms underlying the functioning of these multi-actor H2020 projects. Finally, we describe the multi-level system failures we were able to identify by using this approach.

2. The MINOS analytical framework for identifying multi-level system failures

The foundations for the MINOS analytical framework lie in the combined structural-functional approach to IS analysis developed by Klein Woolthuis et al. (2005), Bergek et al. (2008) and Wieczorek and Hekkert (2012). These scholars argued that an IS can only be fully understood by recognising that its structure (i.e., an IS's foundational components) and its functions are mutually dependent (Markard and Truffer, 2008; Kieft et al., 2017). Consequently, the structural analysis is increasingly complemented with a functional analysis wherein processes vital to the IS performance are defined as 'functions'. This clarifies the dynamics within the system, thus revealing the IS performance at a certain moment in time (Wieczorek and Hekkert, 2012; Lamprinopoulou et al., 2014; Kieft et al., 2017). Therefore, we follow the stepwise approach developed by Wieczorek and Hekkert (2012). To account for the multi-level nature of our analysis, we added an initial step, namely, the identification and description of the relevant IS levels.

2.1. Step 1. Identifying the relevant IS levels and their relationships

Here, we define each individual level of IS relevant to multi-actor H2020 projects (Table 1, Fig. 1). At the micro-level, two types of IS are classified: the H2020 project, as the multi-actor co-innovation partnership, and the participating partner organisations or individual actors (Partner). An H2020 project consortium is composed of multiple Partners, while partner organisations or individual actors can be involved in multiple H2020 projects. At the macro-level, two IS levels are identified: the national AIS (NAIS), in which each Partner in the H2020 project is embedded, and the EU AIS which reflects the ambition set by the European Commission (EC) to build a European Research (and Innovation) Area and the development of European IS under the Horizon Europe programme (European Commission, 2020).

The distinction between the EU AIS and the NAIS can be made based upon the participating IS actors (Fig. 1). Some actors are only active in the EU AIS, such as European-wide interest organisations or 'umbrella' organisations. Nevertheless, in terms of actors, the EU AIS and the NAIS can overlap as actors can have both an EU and national presence. Examples include National Rural Networks or organisations or individual actors that are Partners in H2020 projects.

2.2. Step 2. What is the structure of the IS levels?

The IS structure refers to the basic building blocks listed in Table 2. Both the AIS and OIS approaches refer to actors, innovation network or interactions, institutions and infrastructure or resources. Van Lancker et al. (2016) also include the innovation process. However, this is used in their analysis to structure the different functions along a timeline. Following Bergek et al. (2008) and Hekkert et al. (2011), we understand the innovation process as the addition of a temporal dimension to the

Table 1
Definitions of the relevant Innovation System levels (based upon Lamprinopoulou et al., 2014 for the macro-level IS; Van Lancker et al., 2016 for the micro-level IS).

Name	IS level	Definition
H2020 project	Micro	A network of diverse actors, collaborating within a multi-actor co-innovation project to generate, develop and utilise new concepts, shaped by institutions and policies at both national and EU levels.
Partner	Micro	An organisation, consisting of a network or group of individuals, or an individual actor collaborating with diverse actors in an (multiple) innovation process(es), to generate, develop and utilise a new concept, shaped by institutions and policies at both national and EU levels.
NAIS	Macro	A network of actors within a country, focused on bringing new products, processes or forms of organisation into (economic) use, together with the country-specific institutions and policies that affect their behaviour and performance.
EU AIS	Macro	A network of actors at the European level, focused on bringing new products, processes or forms of organisation into (economic) use, where they are bound by EU specified institutions and policies that affect their behaviour and performance.

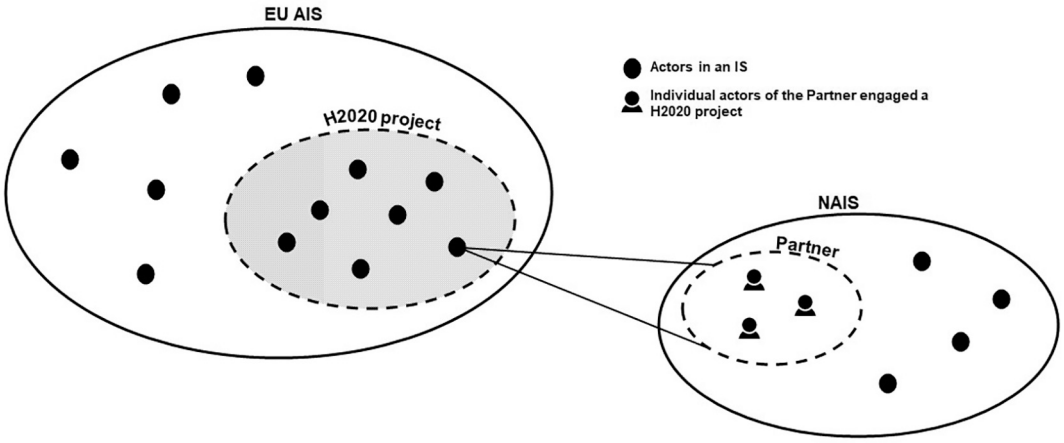

Fig. 1. Illustration of the MINOS and the relationship between the four Innovation System levels.

Table 2
Definitions of structural elements of an Innovation System.

Structural elements	Definition
Actors	IS actors can be organisations or individuals. Actors at the Partner level are most likely individuals. Different categories of actors exist, such as those active in the research domain (e.g., universities, research institutes), the intermediary domain (e.g., advisers or innovation brokers), the enterprise domain (e.g., farm businesses or producer organisations) and innovation influencer domain (e.g., a public body or social interest group) (Lamprinopoulou et al., 2014).
Innovation network or interactions	The innovation network is dynamic, meaning that it plays different roles at different phases of the innovation process (Wieczorek and Hekkert, 2012). In the micro-level IS, the innovation network is most important in terms of ensuring the representation of relevant stakeholders that are not directly part of the 'innovating entity' (Van Lancker et al., 2016). In the macro-level IS, it is understood as the relationships and links between actors, both at the level of networks and at the level of individual contacts (Klein Woolthuis et al., 2005).
Institutions	The 'rules of the game' or 'code of conduct' (Klein Woolthuis et al., 2005). The most commonly used categorisation is that of formal (e.g., regulations, instructions) and informal institutions (e.g., norms, customs, habits).
Infrastructure[a]	We understand infrastructure in the broad sense of the term, i.e., physical (e.g., roads, broadband Internet), knowledge (e.g., expertise, strategic information) and financial (e.g., subsidies, loans) infrastructure (Wieczorek and Hekkert, 2012).

[a] Infrastructure is not a fixed structural element in IS studies (Wieczorek and Hekkert, 2012) and it was also not included in, for example, Lamprinopoulou et al. (2014). However, when linking it to the functional analysis, it is a relevant element to consider in the MINOS framework.

analysis rather than a structural building block of an IS.

2.3. Step 3. How do the IS levels function?

The third step is a functional analysis (Table 3). All functions are listed and operationalised at both the micro- and macro-levels. Although the AIS and OIS frameworks base their functions on slightly different bodies of literature, similar functions can be identified. For example, function '*F0 – Learning and knowledge development*' was not present in the framework of Van Lancker et al. (2016). We added and defined this function at the micro-level IS as well, as we consider it to also be a necessary precondition for a well-functioning system at any level.

When studying functions, weaknesses or strengths in a particular function are not always causes for system failures or well-performing systems. A function's relevance depends on the stage of the innovation process which implies that an analysis of functions along the stages of an innovation process is the best fitted approach (Bergek et al., 2008; Hekkert et al., 2011; Van Lancker et al., 2016). Consequently, structuring the analysis of multi-actor H2020 projects along the different stages of R&I project development and implementation is a well-grounded choice congruent with both the AIS and OIS approaches.

2.4. Step 4. Identification of (multi-level) system failures

The aim of the structural-functional approach is to identify functions which do not perform well based upon underlying issues with the structure of the system. The identification of system failures within an IS was originally an approach within the structural analysis. The integrated framework of Lamprinopoulou et al. (2014) added a functional component to the structural analysis based upon the system failure matrix of Klein Woolthuis et al. (2005). Van Lancker et al. (2016) made the translation to the micro-level. In the system failure identification, the reasons why certain functions are not performing well are explored by looking at the structural components underpinning each function. The different system failures are operationalised in Table 4.

3. Methodology

We used the MINOS framework to analyse the results of 50 semi-structured interviews with key informants in 50 H2020 projects in agriculture, forestry and related sectors falling under the 'multi-actor approach'. These interviews form a subset of a larger database collected in the frame of the H2020 funded project LIAISON (Better Rural Innovation: Linking Actors, Instruments and Policies through Networks). LIAISON strives for a more profound understanding of how different types of co-innovation partnerships function and the reasons why some are more successful than others in supporting innovation. The methodology for the compilation of the complete database and the data collection has been described in detail by Fieldsend et al. (2020) and Fieldsend et al. (2021).

For the 50 multi-actor H2020 projects, 'one telephone call' interviews lasting about one hour were conducted in the period between May and July 2019 by the LIAISON consortium. The LIAISON partners were instructed to interview key informants within the selected partnerships following a standardised semi-structured interview guideline. Key informants were defined as persons with the most complete view of the entire course of the project, from proposal to implementation. Thirty-two of the respondents were project coordinators. The balance of the interviewees were Work Package leaders (4), task leaders (3),

Table 3
Functions in the Innovation Systems at macro- and micro-level (elaboration based upon Bergek et al. (2008), Hekkert et al. (2011) for the macro-level IS and Van Lancker et al. (2016) for the micro-level IS).

Functions	Macro-level IS (EU AIS and NAIS)	Micro-level IS (H2020 project and Partner)
F0 – Learning and knowledge development	Does the IS support sufficient and appropriate knowledge development and opportunities for learning?	Do the innovating actors in the innovating entity combine different types of knowledge and learn from each other?
F1 – Resource mobilisation (financial and human capital)	Does the IS sufficiently support access to and availability of financial, human and physical resources?	Does the innovating entity have access to complementary financial, human and physical resources? Do actors in the innovating entity identify and access the necessary resources?
F2 – Entrepreneurial activities	Are there active entrepreneurs present in the IS? Do they conduct experiments and tests? Are there new entrants in the sector bringing new ideas?	Are the actors identifying new ideas, facilitating interaction with relevant stakeholders and translating trends and opportunities into ideas for innovation?
F3 – Networking activity and knowledge diffusion	Are there opportunities for knowledge sharing in the IS? Are there sufficient networks or interactions between relevant actors present in the IS? Are they able to connect, interact and exchange?	Are there provisions made by the innovating entity to check wishes and needs both with internal and external stakeholders, market and society?
F4 – Available markets for innovation/Support for market development	Are there sufficient and suitable markets available in the IS or is their development supported?	Does the innovating entity identify or develop a suitable market? Is the innovating entity developing means for the diffusion and spread of its innovation?
F5 – Guidance of the search: Strategies, visions, expectations by actors	Is there a clear and shared vision or strategy between actors into which direction the IS should evolve or develop? Are visions and expectations sufficiently aligned to reduce uncertainties?	Does the innovating entity create a clear and shared vision to reduce uncertainty about the idea and clarify/identify win-wins?
F6 – Creation of legitimacy: From idea to uptake?	Is there a balance in the IS between advocacy coalitions or lobbies in support of innovations and vested interests counteracting them?	Does the innovating entity communicate, demonstrate and disseminate the relative advantages of their innovation? Do they take into account the experiences and needs of potential users?

scientific coordinators (4) or respondents responsible for the implementation of the project in their own country (2). In three instances, the interview was done with multiple people at the same time. In two cases, the role of the respondent in the project was not shared. Most respondents identified themselves as 'researchers' (36), but individuals from business (1), education (6), NGO (3), processing or marketing producer organisations (1) or a representative organisation (1) were also interviewed. Two respondents did not specify this information. We included projects which were close to completion as well as those which were still in full implementation phase.

We analysed the structural and functional components of each IS level by coding the 50 interviews using NVivo (QSR International, Doncaster, Australia) in several rounds. In a first round, the seven IS functions were used as categories for coding the interviews. We categorised statements which described the performance of an IS under the functions based upon the operationalisation presented in Table 3. In a second round, a further categorisation was made based upon the structural elements presented in Table 2. By doing so we gained insight into the system failures that occur within each function at the different IS levels. But even more so and of particular interest is that we gained understanding of what we call 'multi-level system failures'. We have used some direct quotations from the interviews to illustrate and support the narrative. They have been re-coded and, where necessary, some noise was added in square brackets '[…]' without changing the original meaning of the quote in order to support anonymisation.

In the results we focus on those system failures that occurred across most of the 50 cases which gave rise to multi-level system failures. This approach allows us to show the added value of analysing the data with

Table 4
Structural system failures in the Innovation Systems at macro- and micro level based upon Klein Woolthuis et al. (2005), Klerkx and Leeuwis (2008) for the macro-level IS, Van Lancker et al. (2016) for the micro-level IS.

System failures	Macro-level IS (EU AIS and NAIS)	Micro-level IS (H2020 project and Partner)
S0 – Infrastructure and resource failure	Does the IS provide sufficient and suitable large-scale physical, financial and knowledge infrastructure for innovation?	Are necessary financial or human resources available and accessible to the innovating entity?
S1 – Institutional failures	**Formal institutional failure** Do formally written and consciously created institutions in the IS provide the appropriate context for innovation? **Informal institutional failure** Does the wider political context, social norms and values, the 'way business is done' stimulate innovation?	**Formal institutional failure** Are the formal arrangements (e.g., written rules, contracts, non-disclosure agreements) suitable and sufficient for the actors in the innovating entity? **Informal institutional failure** Is there sufficient alignment between the actors of the innovating entity in terms of vision, social values and norms, mutual trust, etc.?
S2 – Network failures	**Strong network failure** Are the actors in the IS not locked into their relationships, i.e., is there sufficient room for new information, knowledge and new entrants? Are there no dominant actors in the IS? **Weak network failure** Are actors in the IS well connected resulting in a smart utilisation of complementary knowledge, skills, know-how or capacity?	**Representativeness failure** Are the relevant external stakeholders involved by the innovating entity? Does the innovating entity consist of the relevant actors? **Openness failure** WaIs a proper balance struck in the degree of participation of external stakeholders? **Iteration failure** Is there the right degree of iteration? **Cooperation failure** Is there trust between partners and did the cooperation work well? **Lock-in failure** Are there sufficient actors bringing in new, external information or perspectives?
S3 – Capability and capacity failures	Does the IS support and promote the development of flexibility, learning potential and necessary capabilities (e.g., networking) in dealing with innovation for its actors?	Do actors in the innovating entity have relevant capacities, such as the ability to recognise and use valuable new information or the capacity to build a network?
S4 – Market and dimensional blindness failure	Does the IS consider and deal with certain issues or imperfections related to the market structure (e.g., monopolies, information asymmetries, etc.)?	Do actors look at different system dimensions at the beginning of the innovation process? (e.g., identified possible issues with legislation, well-investigated end-user needs, etc.)

Table 6
Multi-level system failures occurring during the implementation phase of the H2020 project cycle. F2 and F4 were not mentioned by respondents in this phase.

System function	Problem diagnosis	IS levels involved	System failures
F0 – Learning and knowledge development	- **Transparent and open communication** via different channels	Project/ Partner/NAIS	Infrastructural failure and capability/ capacity failure
	- Perception of **non-complementary skills**	Project/Partner	Informal institutional failure
	- **In large partnerships** it is challenging to connect relevant Partners with each other	EU AIS/Project /Partner	Informal institutional failure, weak network failure and openness failure
	- **Rigid division of responsibilities and roles** in grant agreements and work plans	EU AIS/Project /Partner	Weak network failure and formal institutional failure
F1 – Resource mobilisation (financial and human capital)	- **Budget per partner** limits engagement of some partners	EU AIS/Project/ Partner	Weak network failure and infrastructural/ resource failure
F3 – Networking activity and knowledge diffusion	- **In large partnerships** it is challenging to connect relevant Partners with each other	EU AIS/Project /Partner	Weak network failure
	- **Online communication** needs to be complemented with **face-to-face time** but this is not always possible	EU AIS/Project/ Partner	Weak network failure and infrastructure/ resource failure
F5 – Guidance of the search: Strategies, visions, expectations by actors	- **Experienced project coordinator is needed** in terms of multi-disciplinary and multi-actor work	Partner/ Project/NAIS	Capacity/capability failure and informal institutional failure
	- **Size of the partnership** poses challenges to aligning all wishes and needs	EU AIS/Project /Partner	Weak network and lock-in failure and institutional failure
	- **Enthusiasm and willingness** of Partners to work in a multi-actor setting	Project/ Partner/NAIS	Informal institutional failure
F6 – Creation of legitimacy: From idea to uptake?	- **Rigid division of responsibilities and roles in grant agreements and work plans**	EU AIS/Project /Partner	Weak network failure and formal institutional failure
	- **Online communication** needs to be complemented with **face-to-face time** but this is not always possible	EU AIS/Project /Partner	Weak network failure and infrastructure/ resource failure

the MINOS framework. Since the main aim of this paper is to explore how to identify the mechanisms behind the way system failures interact and interconnect across different IS levels, thus affecting the functioning of multi-actor H2020 projects, we only describe those mechanisms which provide evidence for these multi-level system failures. Although this choice leads to a certain bias in the interpretation of the evidence, we believe this is necessary to demonstrate clearly the potential added value of applying the MINOS framework not only to multi-actor H2020 projects, but also to other multinational, multi-actor co-innovation partnerships.

4. Results

In this section we show the added value of applying the MINOS framework to a dataset of 50 semi-structured interviews with H2020 project actors. The most striking results of the structural-functional analysis are summarised in tables, which serve as additional background information in support of the narrative built (i.e., Tables 5,6 and 7).

We structured the key findings according to the three major stages of a project lifecycle, namely consortium development, project implementation and stakeholder involvement and dissemination (Fig. 2). For each stage we describe the most frequently occurring dynamics stemming from the data while indicating under which function they can be categorised in parentheses. We link these dynamics to the system failures and describe the mechanisms by which system failures in one IS level can create system failures in other IS levels, i.e., creating multi-level system failures.

4.1. Consortium development

In this section, we look at the dynamics of bringing prospective Partners together in a H2020 project consortium (Table 5). Typically, consortium development starts with one actor or a core group of actors actively screening project calls *(F2 – Entrepreneurial activities)*. In 42 of 50 H2020 projects, these were actors from the research domain. Our results indicate the existence of a pool of dominant actors (Partners) initiating H2020 project consortium development and bringing together, in the first place, a set of actors who they know and trust. This finding indicates the potential risk of a strong network failure in the EU AIS, where new actors have difficulties in accessing networks to become part of H2020 project consortia. This network failure at EU AIS is strengthened by formal and informal institutions at both EU AIS and the Partner level.

> *"[The coordinator] is one of the experts in the field with ample experience in similar projects. [The coordinator] [him/her]self-initiated the idea of writing the proposal for the call […]"* (Quote 01)

In terms of formal institutions in the EU AIS, the administrative, financial and organisational requirements set for H2020 projects make it challenging for certain organisations to engage. Actors with previous experience and access to the necessary resources to support proposal writing thus have an advantage (*F1 – Resource mobilisation* and *F2 – Entrepreneurial activities)*. At the level of potential Partners**,** the formal institutions that pose barriers to participation in multi-actor H2020 projects are related to mismatches between internal financial planning, formal rules and timing set by the funder or the unwillingness of the Partner to engage over longer periods of time.

> *"[…] partners are selected on the basis of an existing network built on joint work in other projects […]. It was the coordinator who invited the partners."*(Quote 02)

Informal institutions reinforcing the strong network failure in the EU AIS are the general perception that these dominant actors have the necessary capacities and resources available to screen for calls for proposals consistently, interpret them correctly and write high-quality project proposals, combined with the reputation of being respected by proposal evaluators and experienced in coordinating projects of this size. Furthermore, dominant actors tend to prefer Partner organisations with whom they have a track record of familiarity and/or cooperation, which have a favourable reputation in their respective NAIS and experience of working in H2020 projects *(F3 – Networking activities and knowledge diffusion)*. This can also be linked to the detailed call descriptions and limited amount of time in the proposal-writing phase to build up trust from scratch (*F5 – Guidance of the search)*.

The interlocking of the strong network failure with the institutional failures at the EU, H2020 project and Partner levels can lead to a multi-level system failure consisting of the long-term exclusion or underrepresentation of new entrants, more novel Partner organisations or organisations from Member States with lower performing NAIS. However, adapted formal requirements of the funder (EU AIS) for H2020 projects

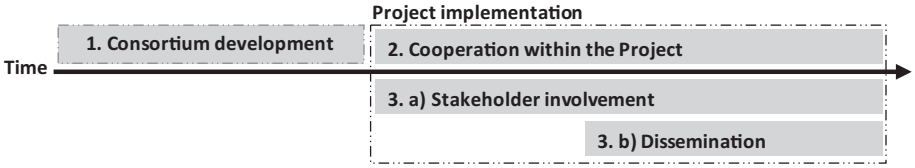

Fig. 2. Structure of the results according to the project lifecycle.

such as a) the multi-actor requirement and b) the criterion of having wide geographical coverage have potential to address this failure. Our results suggest that dominant actors consult a wider array of networks during consortium development to fulfil these requirements. Once a core group of trusted Partners is established, the networking strategy shifts to a wider screening of professional and personal networks to identify suitable Partners. Actors which are a) not (yet) part of the EU AIS or b) have poorer access to pre-existing personal or professional networks both at the EU AIS and at the NAIS are more likely to become engaged at this point *(F1 – Resource mobilisation* and*F3 – Networking activities and knowledge diffusion)*.

For actors that are not part of the EU AIS, it remains key to be in the relevant personal or professional networks at the NAIS level and/or to be known to hold a specific type of knowledge, skill(s) or access to resources (*F2 – Entrepreneurial activities)*. Partner search via organised brokerage events at the EU level was only mentioned by one respondent. Actors active only in the NAIS are unlikely to be contacted, even if they hold relevant resources, unless they are part of the network of one of the core Partner organisations or if they are actively looking for opportunities to become part of a H2020 project *(F2 – Entrepreneurial activities)*. In four of the reviewed multi-actor H2020 projects, a focus group organised by the EIP-AGRI Service Point (EU AIS) was the instigating event for a group of Partners to work together in a H2020 project. But here again, Partners needed to be sufficiently engaged in the NAIS and EU AIS to be aware of these events and be invited to participate.

In conclusion, by looking at the consortium development phase using the multiple IS levels (EU AIS, NAIS and potential Partner organisations) we could see that the position of dominant actors in the EU AIS, when setting up multi-actor H2020 projects, is strengthened on the one hand by network failures in the EU AIS and NAIS and on the other hand by institutional failures at the EU AIS level and with (potential) Partners. Finally, these interlocking failures can affect the functioning of the H2020 projects as it may result in representativeness failure, i.e., some relevant actors are not included, and lock-in failure, i.e., always the same actors are represented. This combination can result in 'group think' which negatively affects the potential for innovation and overall functioning of these multi-actor H2020 projects.

4.2. Project implementation

In this section we elaborate on the processes and challenges identified during the implementation of a multi-actor H2020 project (Table 6). The key governance features of any H2020 project are the grant agreement between the EU and the project coordinator, the partnership agreement between all the Partners in the consortium and the so-called 'Description of Action' (DoA or workplan). The DoA closely replicates the project proposal and forms an essential part of the grant agreement. Hence, decisions made during proposal writing have a substantial impact on the implementation of the project.

> *"[…] the challenge is H2020 grant agreements are defined at the outset, and project proposal evaluators are usually not happy with undefined possible future elements in proposals […]"* (Quote 03)

Formal institutions in the EU AIS in the form of selection and evaluation criteria for assessing the project proposals and the monitoring and evaluation approach during the H2020 project's lifetime can create system failures within the multi-actor H2020 project. Most significantly, respondents indicated the difficulty and importance of maintaining a balance between achieving the geographical and thematic coverage desired by the funder (EU AIS) and having a workable or manageable consortium size with the necessary Partners with the required skills or capacities.

> *"[…] with so many participating partners that you do not always know personally, it was rather a pragmatic choice to divide the work packages."* (Quote 04)

The large partnership size of the multi-actor H2020 projects creates an effective barrier to their functioning in several ways. Firstly, as a coping mechanism, we saw that Partners also during implementation tended to rely mainly on those Partners with whom they have a history of cooperation, thereby reducing the extent of participation of Partners whom they do not know well (openness failure) and increasing the risk of 'group think' (lock-in failure). Secondly, the larger the consortium, the more difficult it becomes to manage the H2020 project and to accommodate sufficient connections and interactions between all Partners. This is necessary to keep all wishes and needs aligned and support knowledge development and sharing during the implementation *(F0 – Learning and knowledge development, F3 – Networking activity and knowledge diffusion*and*F5 – Guidance of the search)* and to ensure that Partners with the correct set of skills or capacities participate in the relevant tasks *(F1 – Resource mobilisation)*. This combination of both too strong ties within a core group of Partners and too weak ties within the multi-actor H2020 project consortium can undermine its capability to fulfil crucial functions (such as, *F0 – Learning and knowledge development* and *F2 – Network activities and knowledge diffusion,* while also complicating *F5 – Guidance of the search)*. Furthermore, it can cause a domino effect, inducing an informal institutional and cooperation failure where the consortium fails to form a common vision or set of norms and values resulting in low levels of trust between Partners.

However, the survey respondents identified factors that can mitigate these challenges. A first factor is the role of coordinators and Partners who have a) experience in working in multi-actor and multidisciplinary settings, b) are willing and capable to work across disciplines and c) are engaged, enthusiastic and motivated *(F0 – Learning and knowledge development)*. Secondly, a positive working environment with clear aims and transparent communication is frequently mentioned as a success factor *(F5 – Guidance of the search)*. Yet, as these H2020 projects are multinational and cover different types of organisations, many of the interactions take place online. The great added value of reserving time and budget for face-to-face meetings and field visits was mentioned by almost all respondents. Finally, working on a topic that receives political or policy attention at different levels (EU AIS, NAIS) creates a higher purpose for the joint work and motivates engagement (*F3 – Networking activities and knowledge diffusion* and*F6 – Creation of legitimacy)*. These are all factors which help to build trust and 'collective responsibility' or respect within the H2020 project, thereby reducing the risk of informal institutional and cooperation failures.

> *"[…] the main challenge is the lack of time for interaction and engagement of the participants."* (Quote 05)

Having in place formal institutions in the form of a clear division of roles, responsibilities and budget is fundamental, especially for activities

Table 5
Multi-level system failures occurring during the consortium development phase of the H2020 project cycle. F0, F4 and F6 were not mentioned by respondents in this phase.

System function	Problem diagnosis	IS levels involved	System failure
F1 – Resource mobilisation (financial and human capital)	- **Formal requirements of H2020 programmes** make it difficult for certain actors to become a partner due to incompatibility with their own rules	NAIS/EU AIS/ Partners	Formal institutional failure
	- **Dominance of actors** from the research domain which have the capacity to actively screen calls and initiate consortium development	EU AIS/ Partners	Strong network failure
	- **In smaller fields of expertise the H2020 calls generate competition** for scarce financial resources	EU AIS/ Project/ Partners	Infrastructure and resource failure
F2 – Entrepreneurial activities	- **Multi-actor requirement:** the formal funding requirements open doors to new actors otherwise not able to engage to become part of H2020 projects	NAIS/EU AIS/ Partners	Formal institutional failure
	- **A network of core actors** select collaborators from previous cooperation and personal networks	EU AIS/ Project	Strong network failure leading to lock-in failure
	- Actors from the research domain are **perceived to be well respected by proposal evaluators** and preferred Partners and coordinators	EU AIS/ Partners	Informal institutional failure
	- **Active support for actors to become part of H2020 projects** by providing public financial resources or support in proposal development	NAIS/ Project / Partners	Infrastructure failure and capability/ capacity failure
F3 – Networking activity and knowledge diffusion	- **Actors formally outside of the EU AIS or in an NAIS with poor networking activity** have difficulty in making themselves known to prospective H2020 projects	EU AIS/ NAIS/ Partners	Weak network failure
F5 – Guidance of the search	- **H2020 calls are directive and have tight deadlines** for proposal submission: drives organisations to work with partners they know and trust.	EU AIS/ Project/ Partners	Formal institutional failure and strong network failure

underpinning the functions *F0 – Learning and knowledge development* and *F2 – Network activities and knowledge diffusion*. These requirements are set by the funder (EU AIS) and formalised in the grant agreement and DoA. There are however occasions where these agreements can hamper both knowledge development and networking activities, as these plans are developed and responsibilities are distributed at the time of proposal writing. This rigidity has the potential to affect interactions between the Partners in the H2020 project. For example, the poor or wrong timing of tasks, not having the most relevant Partners involved in certain tasks or changes in personnel or Partners becoming insolvent during project implementation (capacity failure at Partner level) generated additional complexities within the H2020 projects. Furthermore, striking a balance between an ambitious yet realistic work programme in the light of the financial resources available was mentioned as a key factor for the well-functioning of the H2020 projects. In the cases where work plans were found to be too ambitious or where Partners' budgets were low, Partners' level of engagement and availability within the H2020 project were negatively affected. An additional challenge is that not all types of Partners are equally equipped to deal with formal financial and administrative requirements of the EC, implying that Partners with lower administrative capacity or budget are unlikely to be constantly involved or engaged in multi-actor H2020 projects.

> *"[…] the budget each partner has limits [their] involvement in the project, which means that small partners are unlikely to [engage] constantly."* (Quote 06)

In conclusion, analysis of the project implementation stage by using multiple levels shows that system failures occurring in multi-actor H2020 projects often have their origin in formal institutions, i.e., the grant agreement and DoA (EU AIS). There is substantial pressure on pivotal figures, most often the coordinating Partner, as these formal institutions can induce informal institutional and both weak and strong network failures. This pressure can increase a) a coordinator's reliance on a small set of 'trusted' Partners, who might not necessarily be the most capable in the H2020 project but rather those with the most project experience and b) the likelihood of a breach of trust between this small set of 'trusted' Partners and the H2020 project consortium as a whole. Providing sufficient time and resources for open and transparent communication and giving Partners ample opportunities for interaction are factors that can mitigate this risk of a domino effect of system failures at both H2020 project and Partner level.

4.3. Stakeholder involvement and dissemination

Stakeholder engagement and dissemination were considered to be a quintessential element of multi-actor H2020 projects by the survey respondents. The H2020 project and its constituent Partners both need to cooperate with a 'larger periphery' of engaged stakeholders and disseminate their results to a broader audience (Table 7). Target groups of this involvement and dissemination include a) stakeholders in the various NAIS of the Partners and b) stakeholders in the EU AIS in the form of other H2020 projects and EU actors (e.g., EU-level lobby or representative organisations, the EC). This dialogue is relevant in two ways; to collect input and information from stakeholders external to the H2020 project and to identify their wishes and needs (*F5 – Guidance of the search*), and to disseminate and demonstrate project progress and results *(F3 – Networking activity and knowledge diffusion* and *F6 – Creation of legitimacy)*.

As the main objectives of multi-actor H2020 projects are set out in the project call, elaborated further in detail by the Partners during the proposal preparation stage, and fine-tuned during the implementation stage, the impact stakeholders can have on the direction and implementation of a H2020 project is often limited *(F2 – Entrepreneurial activities* and *F3 – Networking activity and knowledge diffusion)*. The stakeholder involvement and dissemination are to a great extent

Table 7
Multi-level system failures occurring during the stakeholder engagement and dissemination activities of H2020 projects. F4 was not mentioned by respondents in this phase.

System function	Problem diagnosis	IS levels involved	System failures
F0 – Learning and knowledge development	- **Project can create the opportunity** for more networking and knowledge development in NAIS	Project/Partner/ NAIS	Interaction failures
F1 – Resource mobilisation (financial and human capital)	- **More resources** than originally planned or available are needed to involve stakeholders and for dissemination	EU AIS/Project/ Partner	Formal institutional/resource /interaction failures
F2 – Entrepreneurial activities	- **Limited impact of stakeholders** on overall direction of the Project	EU AIS/ Project/ Partner	Formal institutional and interaction failures
F3 – Networking activity and knowledge diffusion	- **Formal reporting requirements and certain EU rules (GDPR)** limit the involvement of stakeholders	EU AIS/Project/ Partner	Formal institutional and interaction failures
	- **Stakeholder involvement** often organised at national or regional level	NAIS/Partner/ Project	Interaction and capacity failures
	- **Position and role of Partner** organisations in the NAIS	NAIS/Partner	Interaction and capacity failures
F5 – Guidance of the search: Strategies, visions, expectations by actors	- **Language barriers**	EU AIS/ Project/ Partner/NAIS	Resource and interaction failures
	- **Large differences** between EU Member States	NAIS/Partner/ Project	Resource and interaction failures
F6 – Creation of legitimacy: From idea to uptake?	- **Specific interest and motivation** of each Partner	Partner/Project	Capacity and interaction failures
	- **Perception by NAIS stakeholders** of the Partner's role or function in the NAIS	NAIS/Partner/ Project	Interaction/capacity/ resource failures

determined by two formal institutions stemming from the EU AIS. Within the grant agreement and DoA commitments are made regarding indicators in terms of communication and dissemination *(F6 – Creation of legitimacy)*. There is the formal requirement by the EC (EU AIS) for continuous external communication, which implies that part of the budget needs to be allocated to this activity and cannot be used otherwise. Additionally, interviewees indicated that the EU's General Data Protection Regulation (GDPR)[2] forms a barrier to engaging effectively with external stakeholders and in feeding their inputs into the project (*F0 – Learning and knowledge development* and *F3 – Networking activities and knowledge diffusion)*. The requirements can make contacting stakeholders more complicated or they are unclear when it comes to exchanging certain types of data between Partners and stakeholders.

> *"A big asset of this project was the involvement of more than 100 companies that were connected to the project through multi-actor platforms. This connection allowed the'harvesting'a lot of real world knowledge that proves vital to the successful delivery of the project"* (Quote 07)

In the EU AIS, the constellation of multi-actor H2020 projects creates opportunities for networking, mostly to disseminate results and outcomes to a) other H2020 projects and b) other actors of the EU AIS. The former is often required by the funding agency. Most H2020 projects see this as an opportunity to join forces in disseminating and communicating their work yet comment that this requires extra resources *(F3 – Networking activities and knowledge diffusion* and *F6 – Creation of legitimacy)*. Networking activities with other organisations in the EU AIS are supported by the networking environment created by EU-level organisations, such as the EIP-AGRI Service Point, in the form of seminars, focus groups and workshops, but also in large European conferences (*F0 – Learning and knowledge development* and *F2 – Networking activities and knowledge diffusion)*.

Most frequently, the dialogue with stakeholders is set up at the national or regional level (NAIS) and Partners use a common approach or methodology developed by the H2020 project such as: 'multi-actor platforms', 'practice-led innovation networks', 'Communities of Practice', 'living laboratories' and 'farmer innovation groups' *(F3 – Networking activity and knowledge diffusion)*. Partners however often have the freedom to adapt and fine-tune the central approach to their own context. Here, two aspects related to the NAIS of each Partner become relevant: the Partner organisations and their position in each respective NAIS and the NAIS functioning.

As a first aspect, the position of the Partners in their NAIS influences their work. The access Partners have to relevant networks within their NAIS and their position within these networks influence the extent to which they can engage successfully with local stakeholders *(F0 – Learning and knowledge development, F3 – Networking activity and knowledge diffusion* and *F6 – Creation of legitimacy)*. This is intrinsically linked to the trust the other actors in the NAIS have in this Partner. Additionally, stakeholder engagement and dissemination activities require differing levels of resources, capacities and skills depending on the Partner. As there are different types of Partners involved in a multi-actor H2020 project, for some of them this will lie close to their usual activities (e.g., advisory services) and for others this will be further away from their expertise (e.g., researchers) *(F3 – Networking activity and knowledge diffusion* and*F6 – Creation of legitimacy)*. The language barrier remains a significant challenge. This covers both the formal language as well as the H2020 project terminology. Some types of actors are better placed in their NAIS than others as not all Partners have the skills or resources available to translate English and project jargon to the local and user languages.

The second aspect is related to the performance of the respective NAIS in terms of the presence of networks, connections and interactions between actors. If these are suboptimal in the NAIS, for example owing to a lack of connections or trust between the NAIS actors, this can complicate or hinder the implementation of the national or regional activities by the Partners, thus undermining the functioning of the H2020 project. Nevertheless, the involvement of a Partner in a multi-actor H2020 project can also create the opportunity for this Partner to increase, support or enhance networks and interactions in both its NAIS and the EU AIS (*F0 – Learning and knowledge developmentand F3 – Networking activity and knowledge diffusion)*.

> *"What is often forgotten in these network projects: it takes a lot of time to set them up and build trust, even with good connections […]. Some countries […] took longer than in others so there is variation between countries."* (Quote 08)

In conclusion, most multi-actor H2020 projects involve stakeholders 'all along the project' and employ a myriad of communication tools to conduct a dialogue with them, focussed on feeding their input and feedback into the H2020 project. The influence of the functioning of both macro-level IS (EU AIS and NAIS) on a H2020 project's success or failure in implementing these activities becomes more prominent. Firstly, in terms of the degree of interactions and connections between

[2] The GDPR is the European Regulation on the protection of natural persons with regard to the processing of personal data and on the free movement of such data. For more information: https://ec.europa.eu/info/law/law-topic/data-protection/data-protection-eu_en.

Table 8
Definition and examples of multi-level system failures.

Multi-level system failures	Definition	Example	Consequence for possible interventions
Multiplier *'line of dominoes falling over'*	A system failure in one IS level, exacerbates or worsens one or more system failures in other IS levels	The formal institutions stemming from the EU AIS consisting of both the requirements to H2020 projects to be eligible for funding (multi-actor, covering 27 Member States) and the grant agreement and DoA can be the multiplier for a range of system failures at both the project (i.e., network failures, informal institutional failure and capacity or capability failures) and the Partner (i.e., resource failures or capacity or capability failures) levels.	Study of just one IS level might only identify system failures which are the result of a multiplier. To fundamentally improve the functioning of that IS, an intervention would need to address the root cause multiplier.
Stacker *'just one brick on top of another brick'*	The interlocking of two or more system failures of different IS levels create a barrier to the functioning of an IS level	The interlocking of the strong network failure with the institutional failures at the EU, H2020 project and Partner level risks creating a multi-level system failure consisting of the long-term exclusion or underrepresentation of new entrants, more novel partner organisations or organisations from EU Member States with underperforming NAIS.	Interventions will need to be made in several IS levels. However, in contrast with the multipliers, addressing either one of these individual system failures will result in the improvement of the functioning of the different IS levels.
Counter-balancing or mitigating factors *'to tip the scale in its favour'*	Having a highly performing IS level can provide a buffer for system failures in other IS levels	Strong, experienced, motivated and open-minded coordinators often succeed in ensuring sufficient interactions and connections between Partners even in (very) large partnerships while also creating enough flexibility in the grant agreement and DoA to address unforeseen circumstances.	Certain pivotal individuals or highly beneficial circumstances can support the well-functioning of a H2020 project. However, these are often context-specific and one-off circumstances. These factors are important indicators that there are other structural issues at play.

actors in the EU AIS and NAIS as well as the position and role the different Partners have in these macro-level IS (network failures). Secondly, some formal institutions set up in the EU AIS create hurdles to the H2020 project in this activity (formal institutional failure). The call for proposals is quite detailed and the H2020 project has made commitments to the EC in the proposal stage, thus limiting the impact stakeholders can have on the direction of the H2020 project.

5. Discussion

5.1. Testing MINOS with empirical evidence: conceptualising multi-level system failures

One key critique on the structural-functional analysis of IS entails that system failures are usually identified as being mutually exclusive and independent from each other. In practice, these failures often interact. For example, Kieft et al. (2017) showed how separate system failures interact with each other and create 'blocking mechanisms' which influence the development and functioning of IS. Kieft et al. (2017), Turner et al. (2016) and Vermunt et al. (2022) found that these mechanisms are often caused by clusters of system failures or problems occurring at different IS levels. Yet, so far, little attention has been paid to how exactly system failures in connected IS levels interlink or interact with each other and how this can be studied. Klerkx et al. (2017) highlight that the different institutional levels are interlinked and reinforce one another, while Hermans et al. (2019) and Vermunt et al. (2022) refer to the role factors external to the IS under study play in the creation of blocking mechanisms. This paper explored how the MINOS framework can go one step further and contributes to this current conceptual and theoretical debate by explicitly situating 'external factors' in linked IS levels. Drawing upon our results, we define and conceptualise different types of 'multi-level system failures' found in the analysis of multi-actor H2020 projects in agriculture, forestry and related sectors.

Multi-level system failures are the result of the interaction and connection between different IS levels and influence the occurrence and severity of system failures in other IS levels. We identify two distinct categories of multi-level system failures and a set of mitigating or counterbalancing factors (Table 8). A first category of multi-level system failures is 'multipliers'. Here, a system failure in one IS level exacerbates or worsens one or more system failures in other IS levels. It can create a domino effect; only addressing the original or root cause system failure is a suitable solution, other interventions would be mere symptom-treatment (Kieft et al., 2017). A second category consists of 'stackers', where multiple system failures across IS levels interlock (or stack upon each other) thus creating a barrier or hurdle to IS functioning. This second category of multi-level system failures can be addressed by solving any of the identified failures, thus overcoming the barrier.

A system failure in one IS level does of course not necessarily create problems with the functioning of different IS levels since these can also be independent problems (Kieft et al., 2017; Vermunt et al., 2022). Nevertheless, the functioning of the micro-level IS is to a great degree dependent on that of the macro-level IS. The extent of this dependence can differ according to the presence or absence of a few counterbalancing or mitigating factors which we mainly found at the micro-level IS. This corroborates findings from Klerkx et al. (2017) which indicate that even when institutional context creates substantial difficulties, individuals have human agency and can act independently of their social structures or transform them. Also de Boon et al. (2021) referred to the influence these psychosocial factors, such as the willingness to (co-)innovate, can have over an innovation process. More exactly, our results show that these factors potentially support the exceptional performance of the IS in crucial functions at given points in time.

The application of the MINOS framework and the conceptualisation of these multi-level system failures allow for a perspective which recognises not only the complexity of multi-actor co-innovation processes, but also the increasingly multi-level reality in which these processes take place. These results confirm the conceptual thinking by, for example, de Boon et al. (2021) on how to better understand the complex process of innovation in agriculture. Studies on 'blocking mechanisms' often focus on those factors internal to a distinct IS, often with a clear geographical scope (cf. Hermans et al., 2019; Vermunt et al., 2022). The MINOS framework and this categorisation of different types of multi-level system failures enables the possibility for a more precise analysis of these mechanisms when they occur at the interface of different interlinked IS levels. In addition, we hope to initiate the development of a conceptual vocabulary to further deepen the analysis of blocking mechanisms resulting from system failures crossing different (types of) IS boundaries.

In the following paragraphs, we elaborate on some key findings of the empirical analysis using the MINOS lens. Firstly, at the level of the multi-actor H2020 projects, we identify two multi-level system failures. Secondly, we suggest three possible intervention strategies related to the implementation of the multi-actor approach in the H2020 programme and its successor, the Horizon Europe programme. In the last paragraph, we make some critical reflections and indicate possible avenues for future studies.

5.2. Multi-level system failures in multi-actor H2020 projects

Applying this framework to multinational, multi-actor co-innovation partnerships in the format of multi-actor H2020 projects allows us to move beyond generic policy or project management recommendations. Rather, we have developed an approach that lets us 'scratch beneath the surface' and identify root causes of both their successes and failures. Recognising the complexity of this type of partnership can help to further improve both their functioning and the IS in which they are embedded and dependent on (EU AIS, NAIS, Partners) (see also the importance attached to the context of co-innovation processes by Ingram et al. (2020) and Klerkx et al. (2017)). The most striking findings were on the one hand related to the presence and overrepresentation of a group of dominant actors in the EU AIS leading to a closed network and on the other hand to the formal institutions framing H2020 projects. These two groups of failures sustain each other.

In line with the findings of Fieldsend et al. (2021), our results showed that there is a group of dominant actors in H2020 projects in agriculture, forestry and related sectors. This can be attributed to the existence of barriers to entry for new actors to the relevant networks at the EU AIS level and translates into the lack of representation and participation of certain types of actors, or actors from some NAIS in multi-actor H2020 projects. One barrier consists of the specific administrative and financial requirements and the lack of experience in the project jargon required for H2020 projects. Indeed, Büttner & Leopold (2015) highlighted that EU project funding has created a distinct 'social world' with a highly codified field of practice, procedural rules and its own jargon. Moreover, these formal and informal institutions of the EU AIS can exclude actors who are not able or willing to adapt to rules of project management set by the H2020 programme.

Furthermore, actors embedded in NAIS which lack certain types of resources or infrastructure and characterised by poor networking activities are underrepresented in EU AIS networks and thus less likely to be contacted to become part of a multi-actor H2020 project as actors focus on using firstly their own personal networks and secondly their professional networks. The results of Hermans et al. (2015) also implied that a critical reflection of the existing structural elements, and thus also the functioning, of the AIS in each country is needed, as national actors might have different needs in order to improve their participation in and contribution to multi-actor H2020 project performance. All these factors inherently provide ever-increasing advantages to those actors that already have these capacities and skills and which are often located in well-performing NAIS. The gap between those actors in the relevant EU or national level networks and those which are not will only widen further without adequate interventions.

Also, the key formal institutions framing multi-actor H2020 projects, i.e., administrative requirements, the call for proposals, the evaluation procedures and the DoA, can hamper their effectiveness. The entire multi-actor H2020 project cycle is characterised by a high degree of rigidity. The limited amount of time and resources available for proposal preparation combined with directive and detailed calls for proposal leaves little space for experimentation and exploration. Insufficient time and resources to allow for building new trust relationships creates an additional barrier for new entrants as Partners tend to rely on those actors with a history of cooperation. Furthermore, this tension between the 'project methodology' and the realities of working with a diversity of Partners and external stakeholders can hamper the quality of the results. Ingram et al. (2020) explained that recognising that all Partners in a project are different and that implementing an early stage analysis via joint reflection on their relationships, interpretation frames, working imperatives and cultures has the potential to strengthen the project. This can also be linked back to the evaluation procedures which lead to large multi-actor H2020 project consortia which have difficulties to ensure ample time and occasions for interactions between Partners during implementation. This again reduces opportunities for reflection and serendipity.

Consequently, although the multi-actor and geographical distribution requirements have created opportunities for new types of actors to participate in multi-actor H2020 projects, on their own they are insufficient to break the reinforcing feedback loop underpinning the persistence of dominant actors in and the barriers to entry of multi-actor H2020 projects. Fostering the inclusion of new and different types of actors while also improving the representation of actors from certain NAIS requires interventions at various IS levels and at different stages of the project cycle or the innovation process. This corroborates other authors' observations, that there remains a need for not only interventions at EU level, but also nationally- or even locally-adapted interventions (see, for example, Hermans et al., 2015; Klerkx et al., 2017). In the following paragraphs, possible intervention strategies addressing these two multi-level system failures are explored.

5.3. Suggestions for intervention strategies to improve the functioning of multi-actor H2020 projects

A first intervention comprises opening up EU-level networks and assisting Partners in finding relevant (new) actors. Hermans et al. (2015) identified vertical and horizontal fragmentation as a barrier to gaining an overview of the NAIS. It is apparent that new entrants find it difficult to make themselves known or to find connections to groups of Partners building multi-actor H2020 project consortia. This can be understood as a call for 'strategic ambidexterity' implying the need for all types of actors to simultaneously explore existing and new networks of actors in order to avoid lock-in failures in innovation projects, while also supporting the continued existence and inclusion of innovation processes which cross and integrate different IS boundaries (e.g., scalar, paradigmatic, sector) (Berthet et al., 2018; Pigford et al., 2018; Turner et al., 2017). There have been initiatives under the successive European Framework Programmes to address this fragmentation via different routes of which the EIP-AGRI is one, flanked by Joint Programming Initiatives and efforts to reduce inequalities in R&I infrastructure between Member States. Networking and brokerage events seem to be inadequate to fundamentally address the strong network failure at EU AIS level as these initiatives only increase fragmentation. As Fieldsend et al. (2021) proposed, earmarking a certain amount of funding for multi-actor H2020 projects for competent new entrants can incentivise consortia to look beyond their usual networks.

Additionally, measures reducing the need to work with trusted Partners can enable new innovative networks to be set up. Firstly, allowing more time during the entire project life cycle, including the consortium development stage, can foster the building up of trust, thus reducing the need to only work with known Partners. It would also create more space for experimentation, exploration and serendipity, thus enabling consideration of the individual and professional composition of the Project consortium which is posited to be necessary for projects to achieve their full innovation potential (Ingram et al., 2020; Klerkx et al., 2017; Turner et al., 2017). Secondly, smaller partnerships possibly with a more restricted geographical focus can provide an environment in which the quality of interactions improves, thus making it more inclusive. The trend for multi-actor projects in Horizon Europe is towards even larger partnerships covering all 27 Member States. Multiple smaller projects working on the same theme or project call combined with a more effective linking between these projects could prove more adequate in opening up EU AIS networks to new actors, while enhancing the quality of interactions within these H2020 projects. In the long term, it can also lead to better functioning NAIS in terms of compatibility of implicit norms and rules with multi-actor, co-innovation processes as a larger diversity of actors can participate and reduce the gap between the dominant actors and newcomers in multi-actor H2020 projects (see also findings from Hermans et al. (2015) and Klerkx et al. (2017)).

Finally, the lack of space, both in terms of time and resources, to have substantive discussions on certain complex, societal challenges reduces

the effectiveness and performance of all four IS levels. Within both the OIS and AIS frameworks there is the implicit assumption that all actors in a system have the common goal of generating new innovations and sharing knowledge while the normative and political aspects of innovation processes are only recently receiving more attention (de Boon et al., 2021; Hermans et al., 2015; Klerkx and Begemann, 2020). In reality, all organisations or societal actors have their own set of objectives which might lead to them impeding innovations which they perceive as threatening the status quo. There is a need to reflect on whether subjects that are controversial at societal and political level are appropriate for multi-actor H2020 projects formed as a response to directive and detailed calls for proposals. One can question both the legitimacy and effectivity of such descriptive calls for proposals as there lies considerable power over the direction of an innovation process with whoever decides on problem and goal formulation (de Boon et al., 2021). Open calls, such as those for Thematic Networks, a specific type of multi-actor H2020 project, or the format of the Interreg programme, where only certain themes are pre-defined, can allow for more substantive involvement of stakeholders at the different IS levels. Leaving more leeway for open discussion within multi-actor H2020 projects on these complex societal challenges has the potential to lead to more effective and inclusive solutions.

5.4. Critical reflections and avenues for future studies

The IS frameworks which we have used as a basis for MINOS focus on failures over successes, which is a common criticism on system failure analyses. Hermans et al. (2015), for example, worked with an Innovation System Performance matrix, thereby highlighting that an IS can have strengths and weaknesses at the same time. Indeed, analysing and comparing 50 multi-actor H2020 projects showed that failures and successes are two sides of the same situation. In further work, a more in-depth empirical exploration of how successes or strengths in one IS level can counterbalance or mitigate failures in other IS levels would offer insights into how to improve the functioning of multi-actor H2020 projects. We have indicated the existence of a connection and interdependence between different IS levels yet the directionality and extent to which the performance of one IS level has an impact on other IS levels is an area for further exploration. This can provide insights into the dynamics between micro- and macro-level IS and how, for example, multi-actor H2020 projects can effectively impact the macro-level IS.

We have applied the MINOS framework solely to multi-actor H2020 projects in agriculture, forestry and related sectors. Our empirical evidence is based upon one key informant interview per project. This approach enabled us to show the explanatory power of the framework and to draw out some first general lessons and patterns which help to prioritise further in-depth research. The in-depth analysis of a more restricted set of cases would enhance the consistency, robustness and conceptual clarity of both the MINOS framework as well as the types of multi-level system failures. Furthermore, it could provide a more detailed elaboration of the micro-level IS such as the Project, the different types of Partners and how some types of actors in macro-level IS are (not) able to become Partners in multi-actor H2020 Projects, for example, individual farmers. Future iterations could also test its flexibility and applicability to the analysis of other types of multinational multi-actor co-innovation partnerships, such as projects under the Interreg programme, other types of R&I projects funded under the EU Framework Programmes or other types of partnerships, for example business clusters, value chain networks or multinational stakeholder platforms.

In the context of more conceptual discussions on, for example, 'mission-oriented' (A)IS (Klerkx and Begemann, 2020), the MINOS framework can be a pertinent analytical tool for the identification of existing mission-oriented AIS by helping to draw boundaries between the different IS levels. For example, in 2021, five innovation missions have been set at the EU level as part of the Horizon Europe programme[3] and a substantial part of the innovation policy is developed at the EU level. The MINOS framework is one of the first frameworks to explicitly conceptualise this level as an (A)IS. Applying the MINOS lens to study how these missions are translated at the national level and how different types of co-innovation partnerships, including but not limited to multi-actor H2020 projects, work on these missions can be an interesting field for further study.

6. Conclusion

In this paper, we have presented a Multi-level Innovation System framework (MINOS) as a way a) to understand the underlying mechanisms of the functioning of multinational multi-actor co-innovation partnerships in the format of multi-actor H2020 projects in agriculture, forestry and related sectors and b) to address the theoretical and conceptual gap in terms of studying the interconnection and interdependence of different IS levels. We have demonstrated that the integration and combination of a macro- (AIS) and micro- (OIS) perspective to IS analysis is both theoretically and empirically compatible. Especially at the micro-level IS, we have complemented the conceptual work of Van Lancker et al. (2016) and the empirical work of Fieldsend et al. (2020) by exploring not only the application of the OIS to multinational, multi-actor project partnerships in the format of H2020 projects, but by embedding its use in a multi-level context and explicitly linking it to macro-level IS.

The application of the framework to 50 multi-actor H2020 projects rather than just one specific in-depth case, provided first insights into dynamics and mechanisms underlying the interactions and connections between the different IS levels. We found that improving the functioning of multi-actor H2020 projects needs more than generic policy or project management interventions at macro- or micro-IS levels. We were able to identify and conceptualise two distinct types of multi-level system failures and the existence of mitigating factors. By defining multi-level system failures as 'multipliers' and 'stackers', this paper represents a first effort to initiate the development of a conceptual vocabulary for system failures and blocking mechanisms which cross different IS boundaries. This can support the drafting of more targeted recommendations for interventions in support of the functioning of innovation processes which span different types of interlinked or embedded IS.

In practice, and for the multi-actor H2020 projects under study, we demonstrate that these projects do not operate in isolation and studying individual projects will yield only limited insights. Therefore, complementary interventions will be needed at all four relevant IS levels, i.e., the EU AIS, NAIS, H2020 project and Partners, in order to solve key failures such as the existence of a group of dominant actors and the barriers to entry created by financial and administrative requirements. The original objective of the EIP-AGRI to create and support synergies between different policy programmes both at EU and Member State levels is a valid one, yet our findings show that interventions exclusively focused on improving the EU AIS will not be sufficient to solve the identified multi-level system failures influencing the performance of multi-actor H2020 projects.

Declaration of Competing Interest

The authors declare that they have no known competing financial

[3] See https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/missions-horizon-europe_en for more information on these missions.

interests or personal relationships that could have appeared to influence the work reported in this paper.

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